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Using Systems Factorial Technology to Investigate Collective Benefit in Group Decision-Making

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While most previous studies indicate that aggregating group-level decisions tends to show a decision advantage in their response speed and/or the accuracy, other studies argue that collaboration does not always result in better performance. In the current study, we investigate whether the discrepancy in group-level performance resulted from the designed task difficulty. Participants were instructed to perform a conjunction search task as a group (participants in a dyad search for targets together) or by an individual (participants search for targets independently) in which participants were asked to search for target Ts among distractor Ls and the task difficulty was manipulated through the number of distractors. We applied Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) to infer the group-decision efficiency via the workload capacity, $C_{AND}(t)$, and $A_{AND}(t)$, which compared the actual group performance with the predicted baseline from individual search performance. The results revealed a collective benefit in both easy and difficult conditions (i.e., $C_{AND}(t)>1$ and $A_{AND}(t)>1$), with a larger benefit in the difficult task condition. Therefore, our results indicate that participants rely more on collaboration when the task is demanding. To conclude, our results suggest that with appropriate task difficulty, group decision-making would be more efficient than individual decisions as the task difficulty increases.

Keywords: *Group decision-making, processing capacity, systems factorial technology, task difficulty*

Extended Abstract

While most previous studies have indicated that aggregating group-level decisions tends to be advantageous in terms of response time and/or accuracy, others have suggested that collaboration does not always result in better performance than individual decisions. In this study, we investigated whether discrepancy in performance was associated with a task's difficulty by using systems factorial technology (Townsend & Nozawa, 1995) as a diagnostic tool to study the group decision-making process. Systems factorial technology provides information regarding workload capacity and enabling actual group performance to be compared with a baseline predicted from each individual's performance. We hypothesized that a collective benefit would be revealed through the super-capacity of group performance. The group's decision efficiency was assessed using a conjunction search task.

Method

Twenty undergraduate students (N_{female} = 10; age: 22.75 ± 2.63 years) at National Cheng Kung University volunteered to participate in this experiment and were randomly divided into 10 dyads. All of the participants had normal or corrected-to-normal vision and signed an informed consent form prior to the experiment. A PC with a 3.20 G-Hz Intel Core i7-8700 processor, Intel UHD graphics 630, and 8 GB of RAM controlled the program and recorded the participants' responses. Stimuli were presented on a 19-inch CRT monitor with a refresh rate of 75 Hz and a display resolution of 1024×768 pixels. The viewing distance was maintained at 60 cm and a chinrest was used to prevent any head movements. The experiment was programmed using Psychtoolbox (http://psychtoolbox.org/) from MATLAB (Mathworks Inc.). Each participant performed under individual and collaborative conditions. For each dyad, two screens were connected to the same computer, with each participant facing their screen and positioned next to their partner at a distance of 55 cm. They were allowed to communicate with each other during the task. To counterbalance the order of the individual and collaborative conditions across dyads, half of the dyads were randomly selected to first perform in the individual condition, while the other half first performed in the collaborative condition. The participants completed the task individually within the individual condition. In the collaborative condition, they were instructed to use whatever strategy they thought was best to work together. As there was only one keyboard for response entry, one participant delivered the response by pressing keys when both members of the dyad reached a consensus, and the responder was swapped after a block. During the experiment, each trial started with a fixation across displayed for a random duration ranging from 500 to 1000 ms. Afterward, a test display included 0, 1, or 2 possible targets "T" and 25 (easy condition) or (difficult condition) distractors "L." The size of the test display was 512×512 pixels. The participants were instructed to search for all of the targets as quickly and accurately as possible by pressing arrow keys as follows: "←" (0 targets), "↓" (1 target), or "→" (2 targets). Specifically, the task consisted of 3 (target number: 0, 1, 2)×2 (task difficulty: easy, difficult) conditions, with each including 50 trials, resulting in 300 trials in total for each session.

Results: The response time results showed a significant main effect of task difficulty ($F(1, 9) = 54.74$, $p < .01$, $\eta^2_p = .86$) because the participants responded faster in the easy condition than in the difficult condition. Social condition had a significant main effect (performing individually or as a dyad; $F(1.12, 10.04) = 10.87$, $p < .01$, $\eta^2_p = .80$). There was also a significant interaction between the social condition and task difficulty ($F(1.02, 9.16) = 15.73$, $p < .01$, $\eta^2_p = .64$). The post hoc comparison showed that in the difficult condition, collaboration resulted in the fastest responses, but this effect was not significant in the easy condition.

The accuracy results showed that task difficulty had a significant main effect ($F(1, 9) = 21.06$, $p < .01$, $\eta^2_p = .70$). Accuracy decreased as task difficulty increased. The main effect of social condition was not significant ($F(1.34, 12.03) < 0.01$, $p = .98$, $\eta^2_p < .01$), and neither was the two-way interaction ($F(1.75, 15.77) = 2.02$, $p = .17$, $\eta^2_p = .18$).

Figure 1 plots the capacity coefficient function for each dyad in easy and difficult conditions and shows that that all of the dyads demonstrated super-capacity, with all $C_{AND}(t)$ values greater than 1 for all times t, and that there were no significant differences between the difficult and easy conditions. To verify the results, we conducted an independent t-test to compare the z-transformed capacity scores (C_{ZAND}), i.e., Houpt-Townsend statistics (Houpt & Townsend, 2012) across task difficulties. The results showed that there were significant differences in the mean C_{ZAND}, $t(9) = 2.99$, $p = .02$, suggesting a larger collective benefit in the difficult condition than in the easy condition. In addition, C_{ZAND} was positive for both difficulty conditions, suggesting super-capacity processing: $t_{\text{easy}}(9) = 5.35$, $p < .01$, $t_{difficult}(9) = 7.99$, $p < .01$. Figure 2 shows $A_{AND}(t)$ for correct and fast responses. The $A_{AND}(t)$ values were consistently larger than 1, suggesting that correct collaborative responses were faster and more frequent than expected (i.e., indicating super-capacity processing). Moreover, for faster response times, the $A_{AND}(t)$ values for the easy condition were larger, while for the difficult condition, they were larger at slower response times. We suspect that this relates to the difference in mean response time at different difficulty levels.

Conclusion

We conducted an experiment based on a conjunction

Figure 1

Plot of the capacity coefficient function in the easy and difficult conditions. The thin lines indicate the capacity coefficient for each dyad, and the thick lines indicate the average group capacity coefficient. The gray line represents the unlimited capacity baseline

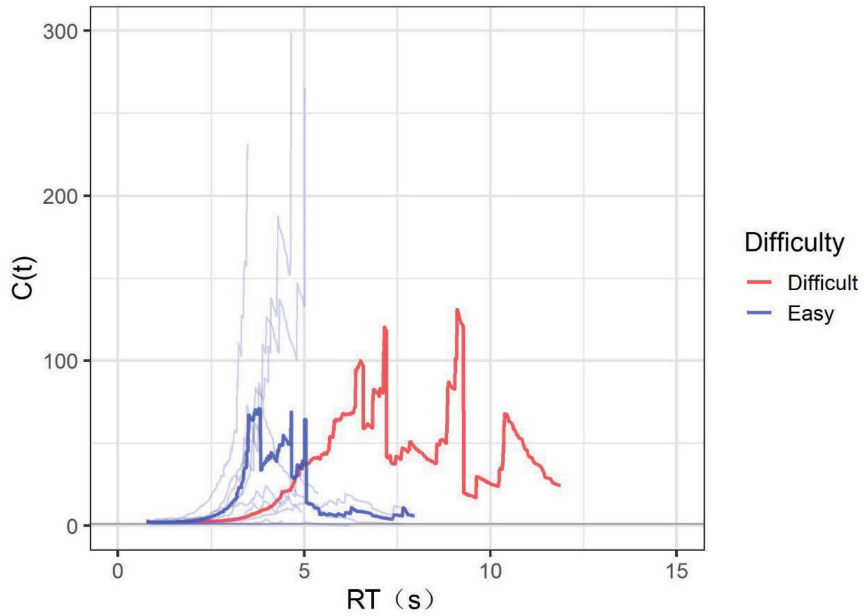
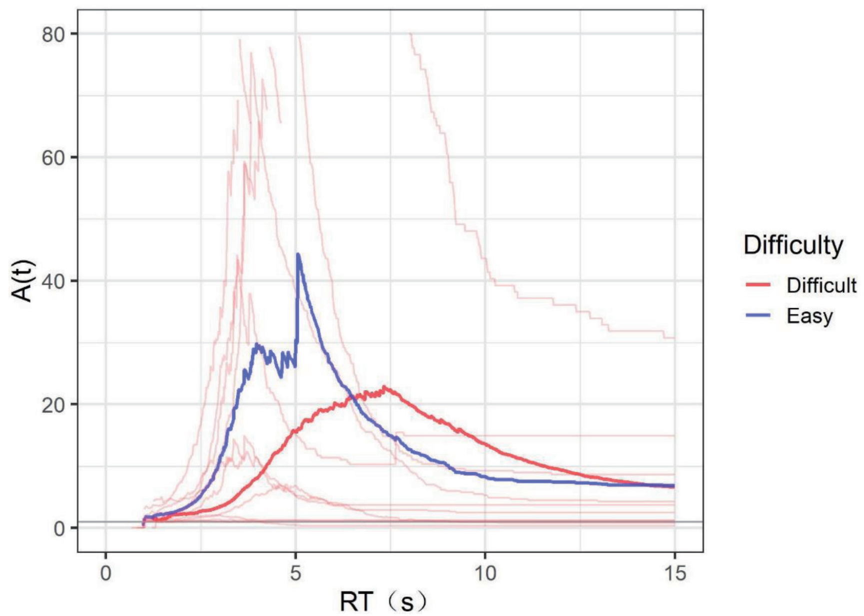


Figure 2

Plot of the assessment functions of workload capacity in the easy and difficult conditions. Thin lines indicate the assessment function for each dyad, while thick lines indicate the average group assessment function. The gray line represents the unlimited capacity baseline



search task to investigate how task difficulty influences group decision performance. The participants were asked to search for 0/1/2 Ts among 25 or 60 Ls individually and collaboratively. The task difficulty was manipulated through the number of distractors. The results showed that the mean response time was slower and that accuracy was lower under the difficult condition. In addition, in the difficult condition, the mean collaborative response time was faster than that of the individual condition, whereas such a difference was not found for accuracy. We then used systems factorial technology to measure group decision-making efficiency. All of the capacity coefficient functions revealed super-capacity, suggesting a collective benefit. This implies that group decision-making can outperform individual decisions under different task difficulties. The capacity coefficient analysis indicated that the difficult condition resulted in a larger collective benefit. Furthermore, the assessment function of workload capacity revealed that the correct group responses were faster and more frequent than expected under both conditions. We suspect that the increased collective benefit is the result of a series of social interactions; that is, there was more communication between participants in the difficult condition.